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To: C. E. Barnes

From: T. Miyahira, G. Swift, Steve Guertin, L. Selva, and D. Nguyen

Subject: Summary of SEE test results from BNL heavy ion test.

Summary of Single Event Effects Test at Brookhaven National Laboratory (BNL) on Feb 23-25, 1999. Seven device types were tested; ADI ADM660 Voltage converter, Lambda ARH2805 DC to DC converter, Samsung and Toshiba 64 Meg DRAMs, NSC LM12H458 ADC, LTN LTC1279 12 bit ADC, INR Power MOSFETs, and Xilinx XQ1701L PROM.

CC: File
S. Agarwal
K. Clark
J. Coss
L. Edmonds
D. Franzen
S. Guertin
S. James
A. Johnston
T. Miyahira
D. Nguyen
B. Rax
M. Sandor
L. Selva
G. Swift
Ken Mehaffey 306-392
Henry Stone 107-102

Single Event Effects (SEE) Test at BNL Van de Graaff
February 23-25, 1999

Tetsuo Miyahira
Gary Swift
Steve Guertin
Luis Selva
Duc Nguyen

JET PROPULSION LABORATORY
California Institute of Technology
Pasadena California

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Introduction

This report covers the following tests:

(1) Latchup test for MARS of ADI ADM660 Voltage Converter.

(2) Dropout test for MIRO of Lambda ARH2805 DC to DC Converter.

(3) SEU test for MSREP of 64 Meg DRAMS from Samsung and Toshiba.

(4) Latchup test for MARS/MSREP of NSC LM12H458 ADC.

(5) Latchup test for MARS of LTC LTC1279 ADC.

(6) SEGR test for MSREP of INR 2N6782, 2N6790, and 2N6786 MOSFET transistors.

(7) Latchup and SEU test for MARS of Xilinx XQ1701L Serial PROM.

The ions used for this series of tests are listed in the table below. LET values are for normally incident ions.

BNL Test Ions **(**February 1999)

Ion	Energy MeV	LET MeV-cm ^{2}/mg	Range µm
F	141	3.36	122.0
Mg	160	6.02	82.9
Cl	210	11.4	63.5
Ni	265	26.6	40.0
Br	276	37.4	35.6
I	343	59.8	32.6
Au	350	82.3	28.0

ADI ADM660 voltage converter latchup test (MARS)

ADI ADM660 Voltage converter was tested for Single Event Latchup (SEL). A preliminary test was done at JPL using the Californium (Cf^{252}) chamber where no latchups were observed. The test at BNL was done using 343 MeV iodine (I^{127}), with a normal incidence LET, LET(0°), of 59.8 MeV-cm^2/mg. Tests were also done at two angles, 45° and 60°, providing a LET(45°) of 84.6 MeV-cm^2/mg and LET(60°) of 120 MeV-cm^2/mg. Two devices were tested. S/N S0880 was tested at room temperature only to a fluence of 9e6 at normal incidence and 1e6 ions/cm^2 at 45° and 60°. S/N S0879 was tested at an elevated temperature of 85°C to a fluence of 1e7 ions/cm^2 at all combinations of three angles and two temperatures. No latchups were observed on any of the tests, thus the ADI ADM660 appears to be immune to latchup to a LET of 120 MeV-cm^2/mg.

Lambda ARH2805 DC to DC converter dropout test (MIRO)

Lambda ARH2805 DC to DC converter multi-chip module (MCM) was tested for Single Event Dropout, a condition where the output voltage shuts down momentarily – several 10's of milliseconds -- and then resumes normal operation. The test effort was shared by Lambda and JPL. Lambda provided test devices and paid for beam time; Dick Miller represented Lambda at the test. JPL provided power supply and shutdown circuitry, output monitoring equipment and run time support. Two ions were used, 343 MeV iodine (I^{127}), with LET(0°) of 59.8 MeV-cm^2/mg and 351 MeV gold (Au^{197}), with LET(0°) of 82.3 MeV-cm^2/mg. Two devices were tested. Three output load conditions were used, 10%, 50%, and 90%. S/N 105 had no dropout with either ion including a test with gold at 30° for LET(30°) of 90 MeV-cm^2/mg. S/N 104 however did experience dropout. The cross-section with iodine was between 1.2E-4 to 1.8E-4 cm^2 and the cross-section with gold was 1.6e-4 cm^2. The LET threshold was not determined because we did not test below a LET of 59.8 MeV-cm^2/mg.

Lambda retained the test parts to look for previously unsuspected circuit and/or component differences, which would explain the large difference in the observed dropout susceptibility of the two parts**. *Post test evaluation by Lambda revealed a disconnected bond wire in the over-current protection circuit on the device (S/N 105) that did not have dropouts***. Thus, the dropout data given above for S/N 104 is the only valid test result, and the Lambda device is susceptible to dropouts.

Samsung and Toshiba 64 Meg DRAMs SEU test (MSREP)

64 Meg DRAMs from Samsung and Toshiba were tested for μdose and SEUs (DRAMs from other manufacturers devices were not available in time). The test was conducted in order to correlate individual ion hits to DRAM memory cell retention time. This data will be used for a NSREC '99 paper on μDose in DRAMs. Five ions were used. The table below summarizes conventional cross section results for the Toshiba devices, but does not include data on retention time or multiple-bit errors, which is still being analyzed.

Ion	Angle	LET_{eff} MeV-cm^2/mg	Fluence /cm^2	# of SEU	Observed σ
F	0	3.36	5.1E+05	6.4E+03	1.3E-02
F	45	4.76	1.0E+06	1.8E+03	1.8E-03
Cl	0	11.4	4.0E+04	1.4E+04	3.5E-01
Cl	45	16.1	1.5E+04	4.4E+03	2.9E-01
Br	0	37.4	2.1E+04	1.1E+04	5.2E-01
Br	45	52.9	1.0E+04	7.3E+03	7.3E-01
I	0	59.8	1.6E+04	1.5E+04	9.4E-01
I	45	84.6	1.0E+04	1.4E+04	1.4E+00
Au	0	82.3	3.4E+03	2.3E+03	6.8E-01

NSC LM12H458 Analog to Digital Converter latchup test (MARS/MSREP)

National Semiconductor's LM12H458 Analog to Digital Converter was tested for Single Event Latchup (SEL). A preliminary test was done at JPL using the Californium (Cf^{252}) chamber. MARS project funded the test hardware development and the Californium test. The californium test resulted in 23 latchups in two hours of exposure for a total fluence of approximately 7E5 ions/cm^2. The MARs project decided not to test this device at BNL because of the californium results. However, the project was concerned about how to relate the californium results to heavy ion results because of the issues of the distribution of ion types and LET of the fission fragments, as well as the effects of the short range. To help resolve this, MSREP funded a limited test at BNL to compare heavy-ion results with those of californium. A summary of the heavy-ion results is provided below. The threshold LET is higher than would normally be expected from the high sensitivity of the device to californium. This implies that the charge collection depth is relatively short so that the effective LET of the californium fission fragments is ~25 to 30 MeV-cm^2/mg.

Ion	Angle	LET_{eff} MeV-cm^2/mg	Fluence /cm^2	# of SEL	Observed σ
Mg	0	6	1.0E+07	0	0.0E+00
Cl	0	11.4	1.0E+07	0	0.0E+00
Cl	30	13.2	1.0E+07	0	0.0E+00
Cl	45	16.2	1.0E+07	3	3.0E-07

LTC LTC1279 Analog to Digital Converter latchup test (MARS)

Linear Technology LTC1279 12 bit Analog to Digital Converter was tested for Single Event Latchup. A preliminary test was done at JPL using the Californium (Cf^{252}) chamber. There were 5 latchups in two hours of exposure for a total fluence of approximately 7E5 ions/cm^2. Two devices, S/N X3926 and X3928, were tested at BNL using three ions. Because of shadowing, angles above 50° did not provide good results. A summary of the results is provided below. This device is extremely sensitive to latchup. The SEL threshold is below 6 MeV-cm^2/mg a very low value.

Ion	Temp	Angle	LET MeV-cm^2/mg	Fluence /cm^2	SEL	σ
F	RT	0	3.4	1.0E+06	0	
F	RT	45	4.8	1.0E+06	0	
Mg	RT	0	6.0	1.0E+06	4	4.0E-06
Mg	RT	45	8.5	1.0E+06	4	4.0E-06
Mg	RT	50	9.4	1.0E+06	6	6.0E-06
Mg	85C	0	6.0	1.1E+06	6	5.5E-06
Mg	85C	45	8.5	1.0E+06	5	5.0E-06
Cl	RT	0	11.4	1.0E+06	8	8.0E-06
Cl	RT	45	16.2	1.0E+06	10	1.0E-05
Cl	85C	0	11.4	1.0E+06	10	1.0E-05
Cl	85C	45	16.2	1.0E+06	15	1.5E-05

A destructive latchup test was done at JPL using the californium source. To defeat device latchup protection system, the power supply over-current clamps and current thresholds were set to 2 amps, maximum current the power supply will provide. The test was done in two steps.

For step one, the device was allowed to latchup and was left in the latched state for over twenty minutes. While in the latched state, the device was not functioning properly. The functionality of the device is monitored by feeding the output of the ADC being tested into a DAC and comparing the input signal (1kHz sine wave) going into the DUT to the analog output from the DAC with a scope. While in the latched state, the output of the DAC swung from approximately 0 volts to VDD/2, in sync with the input signal. The output looked more like a square wave instead of a sign wave of a properly working device. DUT power was cycled off and then turned back on to see if the device had been damaged. The device was functional when power was reapplied. The supply currents were slightly different, A_Idd dropped from 13mA to 12mA, A_Iss went from approx. 0mA to 0.1mA and D_Idd increased from 0.3mA to 0.4mA.

For step two, the device was allowed to latchup and left in the latched state overnight. The data log showed that the device current for AVdd held at approximately 117 mA and gradually dropped to approximately 90 mA after three hours and thirty-seven minutes. The current then rose to 527mA and began to slowly fall to 420mA at which point, the currents abruptly rose to 651mA for A_Idd and 937mA for A_Iss before falling to near zero on A_Idd and 23mA on A_Iss. Power cycling did not restore device operation.

INR 2N6782 MOSFET transistors SEGR test (MSREP)

International Rectifier's 2N6782 (100V), 2N6790 (200V), and 2N6786 (400V) MOSFET transistors were tested for Single Event Gate Rupture. The tests were done using two ions, 276MeV Bromine(Br^{79}), LET(0°) =37 MeV-cm^2/mg, and 350 MeV Iodine (I^{127}), LET(0°) =59.8 MeV-cm^2/mg, irradiation angles, and gate-drain voltage combinations. The data will be used for a NSREC publication.

Xilinx XQ1701L PROM SEU and SEL test (MARS)

Xilinx XQ1701L PROM was tested for SEU and SEL. Five ions were used to characterize these device (141 MeV Fluorine, LET(0°) = 3.4 MeV-cm^2/mg), (210 MeV Chlorine, LET(0°) =11 MeV-cm^2/mg), (265 MeV Nickel, LET(0°) = 27 MeV-cm^2/mg),(276 MeV Bromine, LET(0°) = 37 MeV-cm^2/mg), and (343 MeV Iodine, LET(0°) = 60 MeV-cm^2/mg). Latchup threshold was approximately LET=50 MeV-cm^2/mg, SEFI threshold was approximately LET=10 MeV-cm^2/mg, and SEU threshold for the address counter was between LET=7 to 10 MeV-cm^2/mg.